

An Adaptive Robotic Tablet Gaming System for Post-Stroke Hand Function Rehabilitation

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ABSTRACT

Physical therapy is a common treatment for the rehabilitation of hemiparesis, or the weakness of one side of the body. Stroke is a common cause of hemiparesis. Stroke survivors regularly struggle with motivation and engagement, especially in-between sessions when the therapist is absent from the exercising process. As a solution, we have developed a robotic tablet gaming system to facilitate post-stroke hand function rehabilitation. Healthy subject pilot studies have been completed to verify that this system increases engagement and is capable of encouraging specific therapeutic motions. In the future, a learning model algorithm will be added to the system to assess the patient's progress and optimize the recovery time.

Categories and Subject Descriptors

I.2.9 [Robotics]: operator interfaces, commercial robots and applications

Keywords

Rehabilitation Robotics; Human-Robot Interaction (HRI)

1. INTRODUCTION

Physical therapy is a common treatment for the rehabilitation of hemiparesis, or the weakness of one side of the body. Stroke, which effects roughly 795,000 Americans per year, is a common cause of hemiparesis [1]. The limitations caused by reduced wrist and hand movements are a key factor associated with reduced perception of quality of life [2]. Through physical therapy exercises, patients can regain strength and improve their ability to use weakened body parts to perform daily activities. Unfortunately, physical therapy, in general, is a painful process that patients do not enjoy participating in. Furthermore, the attitude of the patient directly correlates to their compliance and success during physical therapy sessions [3]. Rehabilitation studies have shown that motivating and empowering patients by providing them with the perception of control can expedite the achievement of the patient's rehabilitation goals [4].

The main goal of this research is to discover methods that assist the patient to overcome a struggle with self-motivation, morale, and continuous compliance with respect to the given exercise regimen in-between clinical visits, and furthermore to encourage

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an expedited recovery. A solution is to develop a therapy gaming system that is designed to supplement the therapist in-between sessions. The goals of this system are to expedite the recovery process by increasing engagement, participation, and morale, as well as to adapt to the abilities of the user. To facilitate this process, a learning algorithm will be implemented in the gaming system to allow for patient recovery during a break between therapist visits, such as during the time between the patient exhausting their yearly physical therapy allocation and the start of a new insurance billing year. Robotic gaming and rehabilitation systems exist; however, a knowledge gap still exists for robotic rehabilitation systems for post-stroke hand function rehabilitation as well as for robotic rehabilitation systems that have the capability to learn and adapt to their users' abilities.

2. HAND FUNCTION REHABILITATION GAMING SYSTEM

A hand function rehabilitation gaming system has been created to facilitate supplementary therapy sessions. In its current form, this system, shown in Fig 1, includes an arm robot, a microcontroller, and a tablet. The participant completes wrist flexing exercises while wearing the HandMentor robot, which functions as a wearable sensor. The value of the wrist angle is read from the HandMentor and transmitted via Bluetooth to the tablet. On the tablet, an asteroid destroying game called RoboBlaster, shown in Fig 2, uses the wrist position, which is detected by the HandMentor robot, to determine the position of the spaceship, which continuously fires lasers to destroy asteroids [5, 6].



Figure 1. A participant using the rehabilitation system.

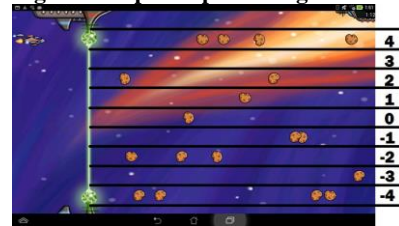


Figure 2. RoboBlaster tablet game, which is played by moving the spaceship (upper right) up and down by flexing the wrist. Lasers (not depicted here) are continuously fired from the spaceship and destroy the asteroids, which approach in the lanes from right.

3. EXPERIMENTATION

Two pilot studies have been completed with healthy adult subjects to verify the concepts of increasing engagement and encouraging therapeutic motions.

3.1 Engagement Experiments

A pilot study was completed in which participants were asked to complete two tasks in a random order. For one of the tasks, the participants were asked to complete wrist exercises until they became bored. For the other task, the participants were asked to play a tablet game that encouraged wrist exercises until they became bored. During both tasks, the participants wore the arm robot to measure wrist trajectories and, in the case of the tablet task, to use the robotic interface as a controller for the tablet game. Participants spent approximately four times longer playing the rehabilitation game before becoming bored than they did with traditional exercises. Upon completion of the experiment, participants were asked a series of twelve questions to quantify their experience. All questions that pertained to engagement, enjoyment, and preference showed that the participants were significantly more satisfied with the gaming experience, as compared to the exercise experience, with p-values less than 0.0001 [5]. This experiment suggests that participants' motivation, enjoyment, and willingness to participate in therapy sessions were improved by the robotic rehabilitation system.

3.2 Motion Experiments

A series of levels were created for the rehabilitation tablet game. Each developed level was designed to encourage one of the motions that mimic wrist motor functions as tested by the Fugl-Meyer assessment, a movement examination that physicians routinely use to assess the recovery of stroke patients. Participants were asked to complete six levels and a control. For each of the levels, encouragement to follow the specific paths was provided by launching the game targets, in this case asteroids, at specific locations and times, thus encouraging the participants to follow the same paths as the targets. For example, a saw-tooth wave of asteroids was used to encourage slow movements between the participants minimum and maximum flexion positions, and asteroids in a square wave were used to encourage alternating holding stretches of the minimum and maximum flexion positions. The results of this experiment showed that participants' motions were significantly different from the control while playing each of the levels. However, upon comparing the actual paths of participants to the paths encouraged by the levels, it was discovered that the participants followed the encouraged path only while encouragement was being provided. An excessive amount of lasers would remain active on the screen and destroy incoming lasers without requiring new participant motions, thus removing encouragement to continue exercising. Also, when the encouraged paths required quick, harsh motions, the participants would follow an aliased version of the intended path [6]. This experiment suggests that game target placement can be used to encourage specific motion. However, to accurately do this, constant encouragement to move at speeds that are comfortable to the participant must be provided.

4. FUTURE WORK

There are several planned additions to this system. For each of these additions, as well as for the current system, additional testing will be performed with healthy subjects and stroke survivors. Once development of the system is complete, the study

will culminate in a long term study of the success of rehabilitation with stroke survivors. In this study, the combination of therapy sessions with a therapist and at-home independent exercising will be compared using traditional exercising and exercising that is encouraged by our robotic rehabilitation system.

4.1 Learning Model

In order to optimize learning of a skill, the difficulty level of the task must be optimized [7]. If a task is too easy, the learner is likely to progress slowly, become bored, or give up. If a task is too difficult, the learner might become frustrated and is also likely to give up. The game will be programmed to follow a normal learning trajectory and will continuously assess the patients' progress. The difficulty of the game will automatically adjust to the optimal difficulty level, removing the requirement for a patient to be able to assess progress independently. The hypothesis is that this will promote engagement, success, and recovery in-between sessions, when the therapist is absent.

4.2 Increasing Engagement and Hand Function Recovery

To further encourage engagement by allowing participants to select from a variety of games, a gaming suite is being developed to be compatible with this system. Also, an interface is being developed to allow for the robotic system to control existing games in the app store. To allow for additional hand function recovery, a second robot is currently being designed and 3D printed that will facilitate finger function rehabilitation. This robot will be designed to be compatible with the same gaming suite but will be controlled via the patient completing squeezing exercises that mimic the Fugl-Meyer assessment. Finger pressure will be read via a pressure sensor and will act as a game input.

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